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Yield Performance and Nutritive Value of Vetch Species Grown on Nitosol and Vertisol Conditions in the Central Highlands of Ethiopia

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Abstract

Five vetch species were evaluated for basic quantitative and qualitative traits at Holetta and Ginchi in the central highlands of Ethiopia during the main cropping season. The experiment was conducted using a randomized complete block design with three replications at each location. The result revealed that a species of vetch respond differently ($P < 0.05$) for most measured traits at both locations. The tallest plant height was recorded for *Vicia dasycarpa* and *Vicia atropurpurea* at Holetta and Ginchi respectively. On the other hand, *Vicia narbonensis* had the shortest plant height at both locations. Vetch species which have an erect growth habit and shorter plant height had a fast biomass production rate than creeping and taller species. Late maturing vetch species gave higher forage dry matter and its morphological fraction yields than early maturing vetch species at both testing sites. *Vicia villosa* gave relatively higher dry matter yield, whereas *Vicia narbonensis* gave the lowest at both locations. Early maturing vetch species had comparatively shorter grain filling period and higher grain sink filling rate than intermediate to late maturing species. The highest number of pods per plant was obtained from *Vicia villosa* at Holetta and *Vicia dasycarpa* at Ginchi whereas *Vicia narbonensis* had the lowest at both locations. The highest pod length was obtained from *Vicia narbonensis* and *Vicia sativa* gave the highest number of seeds per pod. *Vicia sativa* and *Vicia narbonensis* gave the highest seed yield at Holetta and Ginchi, respectively. The highest thousand seed weight was recorded for *Vicia narbonensis* whereas the lowest for *Vicia dasycarpa* and *Vicia villosa* at Holetta and Ginchi, respectively. Moreover, forage quality of vetch species varied across testing sites. *Vicia dasycarpa* had the highest ash content, crude protein content and *in vitro* dry matter digestibility than the remaining vetch species. Generally, late maturing vetch species had better forage dry matter yield and nutritional qualities than other vetch species and with this preliminary result, these vetch species are suggested for proper utilization as livestock feed in the central highlands of Ethiopia. However, further evaluation of the species over locations and years is very important to come up with a better recommendation.

Keywords: Highland, nitosol and vertisol, nutritive value, vetch species, yield performance

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1. Introduction

Ethiopia accounts for about 50% of the highlands of the African continent (FAO, 1986). The Ethiopian highlands, above 1500 meters above sea level, receiving more than 700 mm annual rainfall, and have a mean daily temperature of less than 20°C (Zinash *et al.*, 2001). About 88% of the human population, 70% of cattle and sheep, 30% of goats and 80% of equines are found in this region (Alemayehu, 2004). The central highland of Ethiopia is characterized by crop-livestock mixed farming systems. Livestock is an integral component of most of the agricultural activities in the country. The share of livestock subsector in the national economy is estimated to be 12-16% of the total Gross Domestic Product (GDP) is 30-35% of the agricultural GDP (LMA, 1999), 19% of the export earnings (FAO, 2003), and 31% of the total employment (Getachew, 2003). Despite the enormous contribution of livestock to the livelihood of farmers, availability of poor quality feed resources remains to be the major bottleneck in livestock production in the highlands of Ethiopia (Seyoum and Zinash, 1995; Zinash *et al*., 1995). Lulseged *et al*. (1985) reported that overstocking and overgrazing have resulted in the disappearance of valuable species, spread of unpalatable species such as *Pennisetum shemperi* and land degradation is a common situation in the highlands of Ethiopia. With the rapid increase in human population and increasing demand for food, grazing lands are steadily shrinking being converted to arable lands and availability of adequate feeds has become a major setback to increase livestock production (Muriuki, 2003). Getnet *et al*. (2003) reported that food- forage crop integration with different methods (non-conventional forage production systems) are highly important and appropriate in areas where land shortage is a problem and the agricultural production system is subsistence. Berhanu *et al*. (2003) reported that improved nutrition through adoption of sown forage could substantially increase livestock productivity.

Adaptation and number of annual forage legumes in the highlands of Ethiopia are comparatively very low than mid and low altitudes due to mainly climatic factors. Among many annual forage legumes, an adaptation of vetch is better and promising than the others in the study areas. One attraction of vetch is its versatility, which permits diverse utilization as either ruminant feed or green manure. Vetch is an annual forage legume widely adapted to the highlands of Ethiopia. One of its species, *Vicia atropurpurea* can perform better in the warmer areas like Bako while others also can grow, but their performance is relatively low compared to cooler areas. It grows well on the reddish brown clay soils and the black soils of the highland areas. It has been grown successfully in areas of acid soil with a pH of 5.5-6 (IAR, 1980). Forage Legumes like vetch is rich sources of nitrogen for livestock with cheaper prices compared to concentrates especially in developing countries (Seyoum, 1994). Getnet and Ledin (2001) also found that vetch has a higher crude protein content compared to many other tropical herbaceous legumes. The contribution of vetch (*Vicia spp*.) in crop-livestock production systems in different parts of the world are well recognized (Caballero *et al.,* 2001). Its high value as a protein supplement for ruminants on low quality diets has been recorded (Berhanu *et al*., 2003). Previous evaluations of vetches were done mainly on environmental adaptation and biomass yield, but there is no wide assessment of vetch species with respect to growth features, forage and seed productivity, forage quality, and digestibility. Therefore, this study was conducted to evaluate different vetch species for basic quantitative and qualitative traits to address the feed demand of mixed farming systems of Ethiopia.

2. Materials and Methods

2.1 Description of the Study Sites

The experiment was conducted at the Holetta Agricultural Research Center (HARC) and Ginchi sub center during the main cropping season of 2009 under rain fed conditions. HARC is located at 9°00'N latitude, 38°30'E longitude at an altitude of 2400 masl. It is 34 km west of Addis Ababa on the road to Ambo and is characterized with the long term (30 years) average annual rainfall of 1055.0 mm, average relative humidity of 60.6%, and average maximum and minimum air temperature of 22.2°c and 6.1°c, respectively. The rainfall is bimodal and about 70% of the precipitation fall in the period from June to September while the remaining thirty percent falls in the period from March to May (EIAR, 2005). The soil type of the area is predominantly red nitosol, which is characterized by an average organic matter content of 1.8%, total nitrogen 0.17%, pH 5.24, and available phosphorus 4.55ppm (Gemechu, 2007). The Ginchi sub center is located at 75 km west of Addis Ababa in the same road to Ambo. It is situated on 9°02'N latitude and 38°12'E longitude with an elevation of 2200 meters above sea level, and characterized with the long term (30 years) average annual rainfall of 1095.0 mm, average relative humidity of 58.2%, and average maximum and minimum air temperature of 24.6°c and 8.4°c, respectively. The site has a bimodal rainfall pattern with the main rain from June to September and short rain from March to May (EIAR, 2005).

The soil of the area is predominately black clay vertisol with organic matter content of 1.3%, total nitrogen 0.13%, pH 6.5 and available phosphorus 16.5 ppm (Getachew *et al*., 2007).

2.2. Experimental treatments and design

The study was executed using five vetch species, namely *Vicia sativa*, *Vicia villosa*, *Vicia narbonensis*, *Vicia dasycarpa* and *Vicia atropurpurea*. Among these, the first three vetch species were introduced from the International Center for Agricultural Research in the Dry Areas (ICARDA) while the remaining two species were introduced from Australia. The experimental fields were prepared following the recommended tillage practice and a fine seed bed was used at planting. At Ginchi site, sowing was done on camber-beds to improve drainage and reduce water-logging problems of vertisol. The experiment was conducted on a Randomized Complete Block Design (RCBD) with three replications. Seeds were drilled in rows of 30 cm on a plot size of 2.4 m × 4 m = 9.6 m^2, which consisted of 8 rows.

Based on an experimental design, each treatment was assigned randomly to the experimental units within a block. The species were sown according to their recommended seeding rates are 25 kg/ha for *Vicia villosa*, *Vicia dasycarpa* and *Vicia atropurpurea* whereas 30 kg/ha for *Vicia sativa* and 75 kg/ha for *Vicia narbonensis*. At sowing, 100 kg/ha diammonium phosphate (DAP) fertilizer was uniformly applied to all treatments at both locations. The two rows next to the guard rows were used for determination of number of pods per plant, pod length per plant and number of seeds per pod. The two rows prior to the inner two rows were used to evaluate the proportion of morphological fractions, forage and morphological fraction yields and forage quality. The remaining two rows were used for seed yield determination. The first hand weeding was made thirty days after crop emergence and the second weeding was done thirty days after the first weeding. Generally, maximum cares were taken in the experimental plots to reduce the possible yield limiting factors which could affect the performance of vetch species.

2.3 Data collection and measurements

i) Days to different phenological stages

Days to 50% flowering (forage harvesting stage- when half of the plants in the plot set flowers), and days to seed maturity (seed harvesting stage- when stems, leaves and pods attain typical color and seeds inside pods begin to dry) were counted from days to emerge to the date when plants reach the respective growth stages.

ii) Plant height at different growth stages

Plant height (stretched and unstretched) was measured from the ground to the tip of the plant at the time of 50% flowering (forage harvesting stage). Six plants were randomly taken from each plot and their stretched and un-stretched heights were taken at forage harvesting stage.

iii) Forage yield, the proportions of morphological fractions and their yields

For determination of aerial biomass yield, species of vetch were harvested at 50% flowering. The weight of the total fresh biomass yield was recorded for each plot in the field and the estimated 1 kg (two paper bags each containing about 500 g sample) of their representative samples were taken from each plot to the laboratory. The first estimated 500 g sample taken from each plot was weighed to know the sample fresh weight using sensitive table balance and oven dried for 72 hours at a temperature of 65^{o}c. The oven dried samples were weighed to determine dry matter yield, and then used for laboratory analysis to determine chemical composition and *in vitro* dry matter digestibility of vetch species. The second estimated 500 g sample taken from each plot was weighed to know the total sample fresh weight using sensitive table balance and manually fractioned into leaf, stem, and green pod and flower. The morphological parts were separately weighed to know their sample fresh weight, oven dried for 72 hours at a temperature of 65^{o}c and separately weighed to estimate the proportions of these morphological parts. The proportion of each morphological fraction in percent was then computed as the ratio of each dry biomass fraction of total dry biomass multiplied by 100. Leaf, stem, and green pod and flower yields t ha^{-1} were also estimated by multiplying each proportion of morphological fraction of total dry biomass yield and then divided by 100. Biomass production rate also computed by dividing the above ground biomass yield to a number of days to 50% flowering and expressed as kg ha^{-1} day^{-1}.

iv) Seed yield and other related traits (parameters)

Six plants were randomly taken and uprooted at seed setting stage from two destructive sampling rows of each plot for determination of number of pods per plant. Six pods were then randomly taken to measure pod length and the number of seeds per pod was counted. The inner most two rows of each plot were maintained for seed yield determination. The plants were harvested at ground level at the optimum seed harvesting time and total seed yield was determined from two rows after threshing and winnowing. Seed samples were taken and oven dried at 100°c for 48 hours to adjust moisture content of 10%, a recommended percentage level for legumes (Biru, 1979). Seed yield (t ha^{-1}) and thousand seed weight (g) were then calculated at 10% moisture content. Grain filling period (GFP) and grain sink filling rate (GSFR) were also used to determine seeding yield related performance. Number of days between days for flower initiation and days to seed maturity is known as GFP, while GSFR is calculated as the ratio of grain yield to a number of days from flower initiation to seed maturity and expressed as kg ha^{-1} day^{-1}.

v) Chemical analysis and in-vitro dry matter digestibility

The oven dried samples were ground to pass through a 1 mm sieve size for laboratory analysis. Before scanning, the samples were dried at 60^{o}c overnight in an oven to standardize the moisture and then 3 g of each sample was scanned by, the Near Infra Red Spectroscopy (NIRS) with an 8nm step. The samples were analyzed in % dry matter (DM) basis for Ash, crude protein (CP), Neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), and *in vitro* dry matter digestibility (IVDMD) using a calibrated NIRS (Foss 5000 apparatus and Win ISI II software). This is one of the recent techniques that uses a source of producing light of a known wavelength pattern (usually 800- 2500nm) and that enables to obtain a complete picture of the organic composition of the analyzed substance/materials (Van Kempen, 2001). It is now recognized as a valuable tool in the accurate determination of the chemical composition, digestibility parameters and gas production parameters of a wide range of forages (Herrero *et al.*, 1997).

2.4. Statistical analysis

Analysis of variance (ANOVA) procedures of SAS general linear model (GLM) was used to compare treatment means (SAS, 2002). The F-test for homogeneity of variance was carried and its value was computed as the ratio of the two error mean squares, the larger error mean square in the numerator and the smaller error mean square in the denominator (Gomez and Gomez, 1984). According to Gomez and Gomez (1984), the error variances could be considered homogeneous when the error mean square ratio was not greater than the tabulated F-value. Logarithmic, square root and arcsine (angular) transformations were used for data which couldn’t exhibit homogeneity of variance for agro-morphological and quality parameters according to Gomez and Gomez (1984).

Duncan Multiple Range Test (DMRT) at the 5% significance was used for comparison of means. The data were analyzed using the following model.

$$Y_{ijk} = \mu + T_i + L_j + (TL)_{ij} + B_{k(j)} + e_{ijk},$$

Where, the Y_{ijk} = measured response of treatment i in block k of location j, μ = grand mean, the T_i = effect of treatment i, L_j = effect of location j, TL= treatment and location interaction, $B_{k(j)}$ = effect of block k in location j, and e_{ijk} = random error effect of treatment i in block k of location j.

3. Results and Discussion

3.1. Days to forage and seed harvest

Days to forage harvest for species of vetch showed significant ($P < 0.05$) difference at both locations (Table 1). Though Ginchi site is relatively warmer than Holetta, early maturity for forage and seed were recorded at Holetta than Ginchi. This could be due to high and extended rainfall at Ginchi during the cropping season that encouraged vegetative growth and delayed forage and seed harvesting stages. On average about 10 and 20 more days were required to harvest forage and seed yield respectively at Ginchi compared to Holetta. This indicates the different response of the tested species for these important agronomic traits at both locations. The result indicated that 83.3 to 112.2 and 96.8 to 124.7 days were required after emergence of the seedlings for forage harvesting at Holetta and Ginchi respectively. *Vicia narbonensis* was significantly early ($P < 0.05$), while *Vicia atropurpurea* significantly late ($P < 0.05$) for forage harvest at both locations. Getnet *et al*. (2003) also reported that species such as *Vicia narbonensis* and *Vicia sativa* are relatively earlier maturing than the other vetch species. The variation in forage maturity is an important agronomic trait to select companion crops for maximum production. Getnet *et al*. (2003) also reported that days to maturity had an advantage of selecting companion or mixture crops that best synchronizes to the days to maturity for better compatibility and forage yield.

The days to seed maturity of vetch species also showed a very similar trend to days to maturity for forage at both locations (Table 1). *Vicia narbonensis* showed significantly earlier ($P < 0.05$) than the remaining species at both locations. On the other hand, *Vicia villosa* was significantly late ($P < 0.05$) for seed harvest at Holetta but not significantly late with *Vicia dasycarpa* and *Vicia atropurpurea* at Ginchi. According to Getnet *et al*. (2003), *Vicia narbonensis* and *Vicia sativa* are early maturing; *Vicia dasycarpa* and *Vicia atropurpurea* are intermediate; and *Vicia villosa* is late maturing species recommended and utilized in the highlands of Ethiopia. Phenology (earliness and lateness) of vetch species has a great effect on seed yield productivity. *Vicia narbonensis*, *Vicia sativa* and *Vicia dasycarpa* should be grown for seed production due to earliness to escape frost months, whereas late maturing species like *Vicia villosa* and *Vicia atropurpurea* should not be advisable to grow for seed purpose at Holetta. All vetch species should be grown for seed purpose at Ginchi. Seed shattering is the common characteristics of most annual forage legumes. The pods on the upper part of the plant are still at grain filling, while those of the lower pods have already reached maturity due to indeterminate growth nature of vetch species which makes seed harvesting stage quite difficult. Hence, seed loss due to shattering problem is very high in the field. However, harvesting of such legumes at optimum maturity period can reduce the loss of seed as well as the weed effect on the succeeding crop. Generally, establishment of seed maturity calendar based on genetic and environmental factors may reduce these problems.

Table 1. Least squares means for days to forage and seed harvest of vetch species grown at Holetta and Ginchi

	Days to forage harvest♦		**Days to seed harvest**	
Species	**Holetta**	**Ginchi**	**Holetta**	**Ginchi**
Vicia sativa	96.1^{c}	107.9^{c}	119.7^{c}	151.3^{b}
Vicia villosa	112.2^{a}	117.4^{b}	149.9^{a}	157.9^{a}
Vicia narbonensis	83.3^{d}	96.8^{d}	113.5^{d}	134.6^{c}
Vicia dasycarpa	105.3^{b}	113.0^{b}	129.7^{b}	156.8^{ab}
Vicia atropurpurea	108.3^{a}	124.7^{a}	135.3^{b}	159.3^{a}
Mean	101.0	112.0	129.6	152.0
CV (%)	0.68	1.01	4.08	4.05
R^2	0.94	0.76	0.9	0.73

♦= Log transformation; Means followed by a common superscript letter within a column are not significantly different from each other at P<0.05.

3.2. Plant height at forage harvest

Plant heights (stretched and un-stretched) for vetch species at forage harvest showed variation ($P < 0.05$) at both locations (Table 2). The vetch species' growth habit can be broadly grouped as erect, creeping or climbing. For instance, *Vicia dasycarpa*, *Vicia villosa* and *Vicia atropurpurea* have creeping or climbing growth habit, whereas *Vicia narbonensis* and *Vicia sativa* have erect growth habit. Hence, due to these differences in growth habit, two types of plant heights (stretched and un-stretched) were taken to evaluate their height performance at both locations. The tallest stretched plant height at forage harvest was recorded for *Vicia dasycarpa* followed by *Vicia villosa* and *Vicia atropurpurea* at Holetta. At Ginchi, *Vicia atropurpurea* was the tallest, followed by *Vicia* *dasycarpa*, and *Vicia villosa*. On the other hand, *Vicia sativa* and *Vicia narbonensis* were the shortest at both testing sites. The average stretched plant height was higher at Ginchi compared to Holetta, which could be attributed to higher and extended rainfall and favorable growing conditions. In addition to genetic variability, soil fertility and environmental conditions could also contribute to the difference in height. There are different methods to integrate forage legumes with food crops especially with cereals. During integration, plant height as well as growth habit should be considered, because it has an impact on compatibility. Studies at Holetta showed that shorter oat varieties were more compatible with vetch than taller varieties regardless of other features such as soil fertility status and fertilizer application (Getnet, 1999). Methods of forage legumes integration with food crops varied with the growth habit of the forage legumes. For instance, a species which has an erect growth habit is more compatible with small cereals in intercropping/under-sowing systems, while creeping or climbing growth habit has better compatibility with large cereals in intercropping/under-sowing systems. Generally, for best compatibility, plant height and growth habit of forage legumes should be considered for optimum yield of companion crops without significant effect of one on the other.

Table 2. Least square means for stretched and un-stretched height at forage harvest of vetch species grown at Holetta and Ginchi

	Stretched height♦		**Un-stretched height**	
Species	**Holetta**	**Ginchi**	**Holetta**	**Ginchi**
Vicia sativa	87.1^b	102.6^b	62.2^a	51.9^c
Vicia villosa	138.3^a	155.2^a	62.9^a	61.8^b
Vicia narbonensis	55.2^c	44.3^c	49.3^b	37.2^d
Vicia dasycarpa	151.6^a	167.0^a	63.2^a	71.3^a
Vicia atropurpurea	136.9^a	185.9^a	62.2^a	66.5^{ab}
Mean	113.8	131.0	60.0	57.7
CV (%)	3.45	4.62	12.94	13.64
R^2	0.87	0.87	0.46	0.73

♦= Log transformation; Means followed by a common superscript letter within a column are not significantly different from each other at $P<0.05$.

3.3. Biomass production rate and number of branches at forage harvest

The biomass production rate and branching performance of vetch species were also highly determined by environmental and genetic variability. Higher biomass production rate and number of branches were recorded at Ginchi than Holetta. Biomass production rate for vetch species showed significant (P < 0.05) difference at both locations and ranged from 12.8 to 50.3 kg ha^{-1} day^{-1} at Holetta, while 15.4 to 63.2 kg ha^{-1} day^{-1} at Ginchi (Table 3). A higher rate was recorded for *Vicia villosa* and *Vicia sativa* at Holetta and Ginchi respectively. On the other hand, *Vicia atropurpurea* had significantly lower (P < 0.05) rate than all species except *Vicia dasycarpa* at both testing locations. Generally, early maturing vetch species had comparatively higher biomass production rate while late maturing species had a lower biomass production rate at both locations. This could be due to the occurrence of a short growing period for early maturing species resulted in a higher biomass production rate when compared with late maturing species. Tamene (2008) reported that there was a significant positive gain in biomass production rate and strong association between grain yield and the biomass production rate in faba bean. Branching/tillering performance is an important consideration during selection of crops for better forage yield and ground cover to reduce soil erosion. Like other agronomic traits, branching performance was also influenced by environmental and genetic factors. The number of branches at forage harvest of species showed significant (P < 0.05) difference at both locations (Table 3). Number of branches at forage harvest ranged from 1.3 to 10.8 and 2.4 to 14.5 at Holetta and Ginchi respectively. *Vicia dasycarpa* and *Vicia villosa* gave the highest branches at Holetta and Ginchi respectively, while *Vicia narbonensis* gave the lowest branches at both locations.

Table 3. Least square means for biomass production rate (kg ha^{-1} day^{-1}**)** and number of branches at forage harvest of vetch species grown at Holetta and Ginchi

	Biomass production rate ♦		**Number of branches**▲	
Species	**Holetta**	**Ginchi**	**Holetta**	**Ginchi**
Vicia sativa	47.3^{ab}	63.2^{a}	8.3^{b}	10.0^{b}
Vicia villosa	50.3^{a}	50.6^{a}	10.1^{a}	14.5^{a}
Vicia narbonensis	47.8^{ab}	61.7^{a}	1.3^{c}	2.4^{c}
Vicia dasycarpa	29.3^{bc}	40.7^{ab}	10.8^{a}	13.8^{ab}
Vicia atropurpurea	12.8^{c}	15.4^{b}	7.0^{b}	10.0^{b}
Mean	37.5	46.3	7.5	10.1
CV (%)	16.44	15.79	12.59	20.31
R^2	0.25	0.21	0.89	0.7

♦=Log transformation; ▲= Square root transformation; Means followed by a common superscript letter within a column are not significantly different from each other at P <0.05.

3.4. Proportions of morphological fractions at forage harvest

The proportions of morphological fractions, including leaf, stem, and green pod and flower in the dry matter basis of vetch species were affected by genetic and environmental conditions at forage harvest. The average proportions of leaf, stem, and green pod and flower were significant (P<0.05) differences among the species of vetch (Table 4). The result revealed that the proportion of leaf was in the range of 23.0 to 36.7% at Holetta and 23.5 to 36.7% at Ginchi. The highest leaf proportion was obtained from *Vicia narbonensis* followed by *Vicia sativa*, *Vicia atropurpurea*, *Vicia villosa* and *Vicia dasycarpa* at both locations. Though *Vicia narbonensis* gave the highest leaf proportion due to its low branching performance and broad type leaf, it couldn't able to give the highest total leaf DM yield per unit area. This might be related to its low total forage DM productivity per unit area. Generally, leaf proportion has a great impact on forage quality and hence should be considered during selection of the forage crop. The variation in morphological characteristics such as leaf, stem and panicle fractions of forage accounts for part of the difference in quality and these characteristics is important in the selection of forage crops that are agronomically suitable and used for various purposes such as hay, silage, grazing etc. in a particular area (Getnet and Ledin, 2001). The highest stem proportion of forage harvest was obtained from *Vicia dasycarpa* at Holetta and *Vicia atropurpurea* at Ginchi, while, *Vicia narbonensis* gave the lowest stem proportion at both locations. This variation in stem proportion could be due to the difference in branching or tillering performance of vetch species at forage harvest. For instance, *Vicia narbonensis* is morphologically similar to *Faba bean* and hence branching performance was lower compared with other vetch species. Generally, species with low branching types had lower stem proportion and vice versa. The green pod and flower proportion of vetch species showed significant (P < 0.05) difference at Holetta but not at Ginchi (Table 4). Proportion of green pod and flower was lower compared with the others morphological fractions such as leaf and stem at forage harvest. Variation in green pod and flower proportion at each testing site could be due to variation in stage of maturity and branching/tillering performance. In general, early maturing vetch species produced a large number of green pod and flower than late maturing species at forage harvesting stage.

Table 4. Least square means for proportions (%) of the leaf, Stem, and green pod and flower fractions on a DM basis of vetch species taken at forage harvest at Holetta and Ginchi

	Leaf		**Stem▪**		**Green pod and flower ▪**	
Species	**Holetta**	**Ginchi**	**Holetta**	**Ginchi**	**Holetta**	**Ginchi**
Vicia sativa	32.0^{b}	34.9^{a}	52.8^{b}	51.7^{b}	18.1^{a}	13.5
Vicia villosa	25.2^{cd}	25.5^{b}	59.6^{a}	61.9^{a}	15.4^{a}	12.6

Vicia narbonensis	36.7[a]	36.7[a]	51.1[b]	48.8[b]	12.1[bc]	14.5
Vicia dasycarpa	23.0[d]	23.5[b]	63.5[a]	63.4[a]	14.1[ab]	13.1
Vicia atropurpurea	28.9[bc]	28.8[b]	63.3[a]	63.6[a]	7.7[c]	7.6
Mean	28.4	29.9	58.1	57.9	13.5	12.3
CV (%)	13.01	12.35	10.32	12.12	16.52	24.22
R^2	0.69	0.68	0.37	0.24	0.34	0.08

■ = arcsin transformation; Means followed by the common superscript letters within a column are not significantly different from each other at *P* <0.05.

3.5. Forage and botanical fraction yields

Among vetch species, dry biomass forage yield and its botanical fraction yields varied across the testing sites at forage harvesting stage. The higher total DM yields and its botanical fraction yields were obtained at Ginchi than Holetta. Accordingly, on average the species gave 33.6, 41.8, 33.2 and 19.1% more total herbage, leaf, stem and green pod and flower DM yields respectively at Ginchi compared to Holetta. Total DM yields were different (P<0.05) at both locations and ranged from 1.39 to 5.84 and 1.99 to 7.62 t ha^{-1}at Holetta and Ginchi respectively (Table 5). *Vicia villosa* gave relatively higher total DM yield followed by *Vicia dasycarpa*, *Vicia atropurpurea*, *Vicia sativa* and *Vicia narbonensis* at Holetta. At Ginchi, *Vicia villosa* produced relatively higher total DM yield followed by *Vicia atropurpurea*, *Vicia dasycarpa*, *Vicia sativa* and *Vicia narbonensis*. Generally, intermediate to late maturing vetch species gave relatively better forage DM yield than early maturing vetch species at both locations. This could be explained in terms of the longer duration of growth, which probably enabled the late maturing varieties to take full advantage of the best growing conditions (Ciha, 1983). Fekede (2004) also reported that intermediate to late maturing oat varieties gave a comparatively higher forage yield than the early maturing oat varieties. Getnet and Ledin (2001) reported that soil type was found to be the most important factor affecting biomass yield and hence herbage production on the well-drained red soil was almost double compared to the black soil. However, in this study comparatively higher biomass yield was obtained on black soil (Ginchi) than the red soil (Holetta) during the cropping season. Because forage crops of this study were sown on camber-bed which minimized the water logging problem of vertisol and resulted relatively in higher biomass yield. Yields of morphological fractions such as leaf, stem and green pod and flower for vetch species had significant (P<0.05) difference at both locations (Table 5). The estimated yields of morphological fractions at forage harvesting stage of vetch species ranged from 0.51 to 1.46 t ha^{-1} for leaf DM; 0.70 to 3.50 t ha^{-1} for stem DM; and 0.17 to 0.90 t ha^{-1} for green pod and flower DM yield at Holetta, while 0.73 to 2.26 t ha^{-1} for leaf DM; 0.97 to 4.72 t ha^{-1} for stem DM, and 0.29 to

1.04 t ha^{-1} for green pod and flower DM yield at Ginchi. Herbage in combination with other characteristics like maturity, proportions of morphological fractions and nutritive value of the herbage yield is useful considerations in selecting the best variety for forage production (Arelovich *et al*., 1995).

Table 5. Least square means for total dry matter yield (t ha^{-1}) and botanical fraction yields (t ha^{-1}) of vetch species grown at Holetta and Ginchi

	Total DM♦		**Leaf DM♦**		**Stem DM♦**		**Pod and flower DM♦**	
Species	**Holetta**	**Ginchi**	**Holetta**	**Ginchi**	**Holetta**	**Ginchi**	**Holetta**	**Ginchi**
V. sativa	5.05^{a}	6.79^{a}	1.46^{a}	2.26^{a}	2.69^{b}	3.49^{b}	0.90^{a}	1.04^{a}
V. villosa	5.84^{a}	7.62^{a}	1.44^{a}	1.93^{ab}	3.50^{a}	4.72^{a}	0.90^{a}	0.97^{a}
V. narbonensis	1.39^{b}	1.99^{b}	0.51^{b}	0.73^{c}	0.70^{c}	0.97^{c}	0.17^{c}	0.29^{b}
V. dasycarpa	5.46^{a}	6.89^{a}	1.25^{a}	1.62^{b}	3.44^{ab}	4.37^{ab}	0.77^{a}	0.90^{a}
V. atropurpurea	5.09^{a}	7.14^{a}	1.45^{a}	2.10^{ab}	3.24^{ab}	4.52^{ab}	0.40^{b}	0.52^{ab}
Mean	4.56	6.09	1.22	1.73	2.71	3.61	0.63	0.75
CV (%)	21.12	21.14	13.24	10.47	9.81	10.26	11.6	19.13
R^2	0.84	0.74	0.7	0.73	0.84	0.79	0.77	0.33

♦= Log transformation; Means followed by a common superscript letter within a column are not significantly different from each other at $P<0.05$.

3.6. Grain filling period and total grain sink filling rate

The grain filling period of vetch species differed significantly ($P < 0.05$) at both locations, ranging from 46.9 to 72.4 days with a mean of 56.2 days and from 70.0 to 79.8 days with a mean of 76.1 days at Holetta and Ginchi respectively (Table 6). The highest grain filling period was recorded for *Vicia villosa* at Holetta and *Vicia sativa* at Ginchi, whereas the lowest period was recorded for *Vicia sativa* and *Vicia narbonensis* at Holetta and Ginchi respectively. In general, most of the species started flowering early and had a shorter grain filling period. However, some of the vetch species in this study showed early to start flowering, but took a longer period to fill the grain. The location had an effect ($P < 0.05$) on grain sink filling rate of vetch species, which ranged from 7.2 to 16.4 kg ha^{-1} day^{-1} with a mean of 11.4 kg ha^{-1} day^{-1} at Holetta and from 26.0 to 41.0 kg ha^{-1} day^{-1} with a mean of 31.6 kg ha^{-1} day^{-1} at Ginchi (Table 6). The rate was the highest for *Vicia sativa* (16.4 kg ha^{-1} day^{-1}) at Holetta and for *Vicia narbonensis* (41.0 kg ha^{-1} day^{-1}) at Ginchi, whereas the lowest rate was recorded for *Vicia narbonensis* (7.2 kg ha^{-1} day^{-1}) at Holetta and for *Vicia dasycarpa* (27.8 kg ha^{-1} day^{-1}) at Ginchi. The grain sink filling rate is directly related to the seed yield. Improvement in grain sink filling rate is an important task for maximum seed yield production of any crop. According to

Yifru (1998), a *teff* grain yield improvement over thirty five years of research has been associated mostly with a corresponding increase in panicle grain sink filling rate and panicle yield. Tamene (2008) also reported that sizeable improvement was made in economic growth rate and biomass production rate in faba bean breeding.

Table 6. Least square means for the grain filling period (days) and grain sink filling rate (kg ha^{-1} day^{-1}) of vetch species at Holetta and Ginchi

	Grain filling period		**Grain sink filling rate♦**	
Species	**Holetta**	**Ginchi**	**Holetta**	**Ginchi**
Vicia sativa	46.9[c]	79.8[a]	16.4[a]	33.9[a]
Vicia villosa	72.4[a]	78.6[a]	10.2[b]	29.1[ab]
Vicia narbonensis	56.9[b]	70.0[b]	7.2[c]	41.0[a]
Vicia dasycarpa	51.8[bc]	78.8[a]	13.6[ab]	26.0[b]
Vicia atropurpurea	53.0[bc]	73.3[ab]	9.5[bc]	27.8[ab]
Mean	**56.2**	**76.1**	**11.4**	**31.6**
CV (%)	**12.85**	**8.0**	**13.17**	**8.86**
R^2	**0.68**	**0.35**	**0.29**	**0.19**

♦= Log transformation; Means followed by a common superscript letter within a column are not significantly different from each other at $P<0.05$.

3.7. Seed Yield Components

The number of pods per plant was counted at the optimum seed setting stage due to indeterminate growth nature of vetch species. The number of pods per plant for vetch species varied significantly ($P<0.05$) at both locations which ranged from 7.6 to 85.3 with a mean of 58.2 at Holetta and 30.6 to 159.1 with a mean of 97.4 at Ginchi (Table 7). The highest number of pods per plant was counted for *Vicia villosa* at Holetta and *Vicia dasycarpa* at Ginchi, whereas the lowest was counted for *Vicia narbonensis* at both locations. In general, branching or tillering nature of the plant has a direct effect on number of pods per plant and hence vetch species with a higher branching or tillering performance has a higher number of pods per plant. The pod length of vetch species differed significantly (P<0.05) at both locations and ranged from 2.7 to 5.4 cm with a mean of 3.8 cm at Holetta and 2.8 to 5.5 cm with a mean of 3.9 cm at Ginchi (Table 7). The result showed that *Vicia narbonensis* had comparatively the longest pod length than other vetch species at both locations. *Vicia villosa* had the shortest pod length at both locations. Pod length has a direct effect on the number of seeds per pod and indirect effect on seed yield. The number of seeds per pod for vetch species varied (P<0.05) at both locations, which ranged from 3.9 to 7.0 with a mean of 4.8 at Holetta and from 4.3 to 7.4 with a mean of 5.2 at Ginchi (Table 7). *Vicia sativa* had significantly higher

(P<0.05) number of seeds per pod at both locations. Numbers of seeds per pod are highly related to pod length and seed size and hence the number of seeds per pod for most vetch species increased with increasing pod length. Though *Vicia narbonensis* had the longest pod length, the highest number of seeds per pod was obtained from *Vicia sativa*, because the seed size of *Vicia narbonensis* is larger than *Vicia sativa*. The early maturing vetch species that are normally erect had larger seed size compared to other tested vetch species. In addition to this feature it was also found that these species had a higher number of seeds per pod. Generally, early maturing vetch species had the highest seed yield due to larger seed size and longer pod length compared to the other tested species.

Table 7. Least square means for number of pods per plant, pod length (cm) and number of seeds per pod of vetch species at Holetta and Ginchi

	No. of pods/plant▲		**Pod length (cm)**		**No of seeds/pod**	
Species	**Holetta**	**Holetta**	**Holetta**	**Holetta**	**Holetta**	**Holetta**
Vicia sativa	32.3[b]	45.7[c]	5.3[a]	5.3[b]	7.0[a]	7.4[a]
Vicia villosa	85.3[a]	41.2[ab]	2.7[b]	2.8[c]	3.9[c]	4.3[c]
Vicia narbonensis	7.6[c]	30.6[d]	5.4[a]	5.5[a]	4.8[b]	5.2[b]
Vicia dasycarpa	85.1[a]	159.1[a]	2.8[b]	3.0[c]	4.0[c]	4.4[c]
Vicia atropurpurea	80.5[a]	110.6[b]	2.7[b]	3.1[c]	4.2[c]	4.9[bc]
Mean	58.2	97.4	3.8	3.9	4.8	5.2
CV (%)	10.62	13.78	5.61	5.93	8.2	8.52
R^2	0.94	0.87	0.97	0.96	0.92	0.9

▲= Square root transformation; Means followed by a common superscript letter within a column are not significantly different from each other at P<0.05.

3.8. Seed Yield and Thousand Seed Weight

The seed yield of vetch species differed significantly (*P* <0.05) at Holetta but not at Ginchi, which ranged from 0.4 to 0.8 t ha^{-1} with a mean of 0.6 t ha^{-1} at Holetta and from 2.0 to 2.9 t ha^{-1} with a mean of 2.4 t ha^{-1} at Ginchi (Table 8). This could be due to the existence of water logging problem on Ginchi soil that highly affected the seed yield performance of vetch species. The highest seed yield was obtained from *Vicia sativa* (0.8 t ha^{-1}) at Holetta and *Vicia narbonensis* (2.9 t ha^{-1}) at Ginchi, whereas the low yield was obtained from *Vicia narbonensis* (0.4 t ha^{-1}) at Holetta and *Vicia atropurpurea* (2.0 t ha^{-1}) at Ginchi. The thousand seed weight of vetch species showed a significant (*P*<0.05) difference at both locations, which ranged from 44.1 to 222.8 g with a mean of 81.7 g at Holetta and from 42.5 to 242.2 g with a mean of 86.3 g at Ginchi (Table 8). The highest thousand seed weight was for *Vicia narbonensis* at both locations, whereas the lowest for *Vicia dasycarpa* and

Vicia villosa at Holetta and Ginchi respectively. Though *Vicia narbonensis* had the highest thousand seed weight, its seed yield was relatively lower due to lower establishment performance at Holetta. Unless the establishment performance is poor, species with high thousand seed weight has a higher seed yield. Getnet *et al*. (2003) and Fekede (2004) also reported that most of the oat varieties with high grain yield showed higher 1000 kernel weight. In general, vetch species (*V. narbonensis* and *V. sativa*) which have an erect growth habit and early maturing had comparatively higher thousand seed weight than creeping growth habit and intermediate to late maturing vetch species. The difference could be due to the inherent variation in seed size complemented with the environmental and soil conditions. This agronomic trait is important for seed rate determination of vetch species. Fekede (2004) also reported that thousand seed weight has got practical significance in estimating the seeding rate for each oat variety in order to ensure that an equal number of seeds could be sown per unit area.

Table 8. Least square means for seed yield (t ha^{-1}) and thousand seed weight (g) of vetch species at Holetta and Ginchi

Species	**Seed yield (t ha^{-1})♦**		**Thousand seed weight (g)♦ ♦=**	
	Holetta	**Ginchi**	**Holetta**	**Ginchi**
Vicia sativa	0.8^{a}	2.7	49.4^{b}	54.7^{b}
Vicia villosa	0.7^{a}	2.3	46.2^{b}	42.5^{b}
Vicia narbonensis	0.4^{b}	2.9	222.8^{a}	242.2^{a}
Vicia dasycarpa	0.7^{a}	2.1	44.1^{b}	43.4^{b}
Vicia atropurpurea	0.5^{ab}	2.0	46.1^{b}	48.8^{b}
Mean	0.6	2.4	81.7	86.3
CV (%)	12.42	5.86	24.51	24.99
R^2	0.32	0.12	0.93	0.93

♦= log transformation; Means followed by a common superscript letter within a column are not significantly different from each other at $P<0.05$.

3.9. Non-fiber contents of vetch species

The ash content of the forage of vetch species in this study showed significant ($P<0.05$) difference at both locations, ranging from 7.7 to 10.4% with a mean of 8.8% and from 6.7 to 9.5% with a mean of 8.3% at Holetta and Ginchi, respectively (Table 9). The average ash content was highest in *Vicia dasycarpa*, and the lowest in *Vicia sativa* at both locations. The high ash content in *Vicia dasycarpa* could be an indication of high mineral concentration. Intermediate to late maturing vetch species had relatively higher ash content than early maturing species, which could be due to differences in proportions and composition of morphological fractions. Fekede (2004) also reported that late maturing or low grain producing oat varieties had comparatively higher ash content in their whole forage DM than early maturing or high grain producing oat varieties. Like that of biomass yield, forage quality was influenced by environmental and genetic factors. Getnet and Ledin (2001) found that forage quality of the biomass was generally affected by sowing method, fertilizer and location (soil type). The concentration of minerals in forage varies due to factors like plant developmental stage, morphological fractions, climatic conditions, soil characteristics and fertilization regime (Greene, 2000).

The CP content also showed significant (P<0.05) difference among vetch species at both locations (Table 9). The CP content of the species at forage harvest ranged from 18.9 to 25.8% with a mean of 22.4% and from 18.9 to 26.0% with a mean of 22.5% at Holetta and Ginchi respectively. *Vicia dasycarpa* had higher (P<0.05) CP content followed by *Vicia atropurpurea*, *Vicia narbonensis*, *Vicia villosa* and *Vicia sativa* at both locations. Getnet and Ledin (2001) reported that vetch has a higher CP content compared to many other tropical herbaceous legumes. They found that the CP content of vetch was 18.9%, which is similar to good alfalfa forage and with this level of CP, vetch could be used as a supplement to roughages for dairy cows. Most of the herbaceous legumes have CP content of >15%, a level which is usually required to support lactation and growth, which suggests the adequacy of herbaceous legumes to supplement basal diets of predominately low quality pasture and crop residues (Norton, 1982). In general, the results of this study indicated that intermediate maturing species such as *Vicia dasycarpa* and *Vicia atropurpurea* had comparatively higher CP content, whereas early and late maturing species such as *Vicia sativa*, *Vicia narbonensis* and *Vicia villosa* had comparatively lower CP content at both locations.

Table 9. Least square means for ash, crude protein and *in vitro* dry matter digestibility contents on (%) DM basis of vetch species at Holetta and Ginchi

Species	**Ash**		**CP▲**		**IVDMD**	
	Holetta	**Ginchi**	**Holetta**	**Ginchi**	**Holetta**	**Ginchi**
Vicia sativa	7.7^{c}	6.7^{d}	18.9^{e}	18.9^{e}	60.47^{e}	60.33^{e}
Vicia villosa	9.0^{b}	7.9^{c}	21.4^{d}	21.6^{d}	66.41^{c}	66.21^{c}
Vicia narbonensis	8.2^{c}	9.0^{ab}	22.4^{c}	22.4^{c}	66.54^{b}	66.37^{b}
Vicia dasycarpa	10.4^{a}	9.5^{a}	25.8^{a}	26.0^{a}	73.39^{a}	73.22^{a}
Vicia atropurpurea	8.7^{bc}	8.3^{bc}	23.4^{b}	23.6^{b}	65.56^{d}	65.45^{d}
Mean	8.8	8.3	22.4	22.5	66.47	66.31

CV (%)	10.01	9.76	0.61	0.95	0.15	0.14
R^2	0.51	0.65	0.99	0.97	1.00	1.00

▲= Square root transformation; Means followed by a common superscript letter within a column are not significantly different from each other at *P*<0.05; CP- Crude protein; IVDMD – *in-vitro* dry matter digestibility.

The *in-vitro* dry matter digestibility (IVDMD) was not different when comparing the two locations, but the species were significantly different at both locations (Table 9). The IVDMD ranged from 60.47 to 73.39% with a mean of 66.47% and from 60.33 to 73.22% with a mean of 66.31% at Holetta and Ginchi respectively. At both locations, IVDMD of *Vicia dasycarpa* was the highest (P<0.05), while *Vicia sativa* was the lowest. The IVDMD values greater than 65% indicate good feeding value (Mugeriw *et al*., 1973) and values below this threshold level result in reduced intake due to lowered digestibility. The IVDMD values observed in this study were above this threshold level for all vetch species except *Vicia sativa* at both locations, which result in higher voluntary intake and digestibility of vetch species and this result also supported by Getnet and Ledin (2001). The IVDMD is positively correlated to the CP content and inversely related to the fiber content (NDF and ADF) and cell wall constituents (ADL, cellulose and hemicellulose) for most vetch species. It was generally observed that early maturing vetch species had lower IVDMD compared to intermediate to late maturity vetch species. This could be due to the presence of higher fiber and cell wall constituents, and lower CP content in the early maturing vetch species than the intermediate to late maturing species. The IVDMD of any forage crop varies with harvesting stage (Zinash *et al*., 1995); fiber and cell wall constituents (Van Soest, 1994; Mustafa *et al*., 2000); proportions of morphological fractions (McDonald *et al*., 1995; Fekede, 2004); soil, plant species and climate (McDowell, 2003).

3.10. Fiber contents of vetch species

The neutral detergent fiber (NDF) content of vetch species differed significantly ($P < 0.05$) at both locations, which ranged from 36.5 to 55.2% with a mean of 48.5% and from 39.5 to 54.3% with a mean of 43.8% at Holetta and Ginchi respectively (Table 10). *Vicia sativa* had higher ($P < 0.05$) NDF content than *Vicia dasycarpa* and *Vicia atropurpurea* at Holetta, whereas *Vicia narbonensis* had the highest ($P < 0.05$) NDF content of all the other vetch species at Ginchi. The NDF contents above the critical value of 60%, result in decreased voluntary feed intake, feed conversion efficiency and longer rumination time (Meissner *et al*., 1991). However, the NDF content of all the tested vetch species was found below this threshold level which indicates higher digestibility. As stems mature, protein content decreases and carbohydrate content increases and at maturity, stems make up as much as 80% of the total DM and NDF, which generally estimates the percentage of the total fiber (cellulose, hemicellulose and lignin) increases due to increases in xylem tissue (Jung and Engles, 2002). However, a high amount of protein is associated with NDF, increasing the ruminal and total tract digestibility (Mustafa *et al*., 2000). In general, early maturing and erect growing type of vetch species had comparatively higher NDF content than intermediate to late maturing and creeping type of vetch species. The acid detergent fiber (ADF) and acid detergent lignin (ADL) contents of vetch species significantly ($P < 0.05$) differed at both locations (Table 10). The ADF content ranged from 22.7 to 38.1% with a mean of 33.2% and from 24.7 to 32.6% with a mean of 28.5% at Holetta and Ginchi respectively. The result revealed that *Vicia narbonensis* and *Vicia villosa* had the highest ADF content at Holetta and Ginchi respectively. On the other hand, *Vicia atropurpurea* and *Vicia narbonensis* had the lowest ADF content at Holetta and Ginchi respectively. The ADL content ranged from 8.5 to 13.7% with a mean of 11.0% and from 6.4 to 9.1% with a mean of 8.2% at Holetta and Ginchi respectively. *Vicia narbonensis* (13.7%) and *Vicia dasycarpa* (9.1%) gave the highest ADL content at Holetta and Ginchi respectively, whereas *Vicia atropurpurea* and *Vicia sativa* gave the lowest at Holetta and Ginchi respectively. The fiber content of a feed is particularly important for determining quality within the parameter of digestibility.

Table 10. Least square means for NDF, ADF and ADL contents on (%) DM basis of vetch species at Holetta and Ginchi

	NDF▲		**ADF**		**ADL▲**	
Species	**Holetta**	**Ginchi**	**Holetta**	**Ginchi**	**Holetta**	**Ginchi**
Vicia sativa	55.2[a]	39.5[b]	35.4[a]	29.3[bc]	10.7[b]	7.6[a]
Vicia villosa	51.6[ab]	43.9[b]	35.3[a]	32.6[a]	11.4[ab]	9.1[a]
Vicia narbonensis	54.4[a]	54.3[a]	38.1[a]	23.8[d]	13.7[a]	6.4[b]
Vicia dasycarpa	44.7[bc]	39.7[b]	34.5[a]	32.8[ab]	10.9[ab]	9.1[a]
Vicia atropurpurea	36.5[c]	41.7[b]	22.7[b]	24.7[cd]	8.5[b]	8.8[a]
Mean	48.5	43.8	33.2	28.5	11.0	8.2
CV (%)	7.79	12.35	13.9	14.86	14.28	13.12
R^2	0.42	0.24	0.47	0.53	0.36	0.41

▲= Square root transformation; Means followed by a common superscript letter within a column are not significantly different from each other at P<0.05; NDF- Neutral Detergent Fiber, ADF- Acid Detergent Fiber, ADL- Acid Detergent Lignin

4. Conclusions

Five vetch species were evaluated for their days to different phenological stages, plant height at forage harvest, biomass production rate, number of branches, morphological fractions, grain filling period, grain sink filling rate, forage yield, seed yield and herbage quality at Holetta nitosol and Ginchi vertisol in the central highlands of Ethiopia. The result revealed that early maturing vetch species had comparatively higher biomass production rate while late maturing species had a lower biomass production rate at both locations. Intermediate to late maturing vetch species gave relatively better forage DM yield than early maturing vetch species at both locations. Early maturing vetch species had the highest seed yield due to larger seed size and longer pod length compared to the other tested species. Vetch species (*V. narbonensis* and *V. sativa*) which have an erect growth habit and early maturing had comparatively higher thousand seed weight than creeping growth habit and intermediate to late maturing vetch species. Nutritional qualities indicated that intermediate to late maturing vetch species had comparatively better ash, CP and IVDMD, but lower fiber content than early maturing vetch species. Generally, late maturing vetch species had better forage DM yield and nutritional qualities than other vetch species and with this preliminary result, this species is suggested for proper utilization as livestock feed in the central highlands of Ethiopia. However, further evaluation of the species over locations and years is very important to come up with a better recommendation than this.

References

Alemayehu Mengistu (2004). *Rangelands Biodiversity: Concepts, Approaches, and the Way Forward*. Addis Ababa, Ethiopia.

Arelovich HM, Miranda R, Horn GW, Meiller C,Torrea MB (1995). Oats varieties: Forage production, nutritive value and grain yield. *Agri. Exp. Sta. Tech.* Bull. No. 109, Cabildo, Argentina. Pp. 3-27,

Berhanu Bekele, Getachew Muhammad, Teshome Galano, Temesgen Belayneh (2003). *Faba Bean and Field Pea Disease Research in Ethiopia.* In: Kemal Ali, Seid Ahmed, B. Surendra, Gemechu Kenneni, M. Rajendra and M. Khaled. (eds.). Food and forage legumes of Ethiopia: Progress and prospects. Proceedings of the workshop on food and forage legumes 22-26 September 2003. Addis Ababa, Ethiopia.

Biru Abebe (1979). *Agronomy Research manual*. Part III formulae and tables. IAR. Addis Ababa, Ethiopia.

Caballero R, Alzueta C, Ortiz LT, Rodrique ML, Baro C, Rebole A (2001). Carbohydrate and protein fractions of fresh and dried common vetch at three maturity stages. *Agronomy Journal.* 93: 1006 – 1013.

Chia AJ (1983). Forage production of triticale relative to other spring grains. *Agron. J.* 75: 610-613.

Ethiopian Institute of Agricultural Research (EIAR) (2005). Holetta Agricultural Research Center/ HARC/ progress report 2005/06. EIAR/HARC.

Fekede Feyissa (2004). *Evaluation of potential forage production qualities of selected oats (Avena sativa L.) genotypes. M.Sc. Thesis.* Alemaya University of Agriculture, Ethiopia.

Food and Agricultural Organization of the United Nations (FAO) (2003). Livestock Sector Brief, Ethiopia. Livestock Information, Sector Analysis and Policy Branch, AGAL.

Food and Agriculture Organization of the United Nations (FAO) (1986). Highland Reclamation Study, Ethiopia. Final report Vol. 1. FAO, Italy, Rome.

Gemechu Keneni (2007). Phenotypic diversity for biological nitrogen fixation in Abyssinian field pea (*Pisum sativum* var. abyssinicum) germplasm accession. Report on independent study for Ph.D. Addis Ababa University Science Faculty.

Getachew Agegnehu, Abraham Feyissa, Gemechu Keneni, Mussa Jarso (2007). Chickpea varietal responses to drainage on vertisol of Ginchi highlands of Ethiopia. Ethiopian Society of Soil Science, *Ethiopian Journal of Natural Resources*. (2): 191-207.

Getachew Feleke (2003). A Review of the Small Scale Dairy Sector- Ethiopia. FAO Prevention of Food Losses Program: Milk and Dairy Products, Post-harvest, Losses and Food Safety in Sub-Saharan Africa and the Near East.

Getnet Assefa, Ledin I (2001). Effect of variety, soil type and fertilizer on the establishment, growth, forage yield and voluntary intake by cattle of oats and vetches cultivated in pure and stands and mixtures. *Animal feed science and technology* 92 (2001): 95-111.

Getnet Assefa, Tekleyohanes Behere, Lemma Gizachew, Mesfin Dejene, Diriba Gillita (2003). *Major herbaceous forage legumes: Some achievements in species and varietal evaluation in Ethiopia.* In: Kemal Ali, Seid Ahmed, B. Surendra, Gemechu Kenneni, M. Rajendra and M. Khaled. (eds.). Food and forage legumes of Ethiopia: Progress and prospects. Proceedings of the work shop on food and forage legumes 22-26 September 2003. Addis Ababa, Ethiopia.

Getnet Assefa (1999). *Feed resource assessment and evaluation of forage yield, quality and intake of oats and vetches grown in the highlands of Ethiopia. M.Sc. Thesis. Swedish University of agricultural science*, Uppsala, PP. 1-19.

Gomez KA, Gomez AA (1984). *Statistical procedure for agricultural research*. Second edition. International Rice Research Institute. John Wiley and Sons Inc.

Greene LW (2000). Designing mineral supplementation of forage programs for beef cattle. *J. Anim. Sci.*,**77**: 1-9.

Herrero M, Jessop NS, Fawcett RH, Murray I, Dent JB (1997). Prediction of the *in vitro* gas production dynamics of kikuyu grass by near infrared reflectance spectroscopy using spectrally-structured sample populations. *Animal Feed Science and Technology,* 69(1997): 281-287.

Institute of Agricultural Research (IAR) (1980). *Hand book on pasture and forage crops for animal feeding in Ethiopia*, 1st ed. Addis Ababa, Ethiopia.

Jung HG, Engels FM (2002). Alfalfa stem tissues: cell-wall deposition, composition, and degradability. *Crop Sci.* 42: 524-534.

Livestock Marketing Authority (LMA) (1999). Annual report, Addis Ababa, Ethiopia.

Lulseged Gebrehiwot (1985). *The status of pasture and forage research and development in Ethiopia*: In: Beyene Kebede & L.J. Lamboune (eds.) The status of Livestock pasture and forage research and development in Ethiopia. IAR proceeding, 8-10 January, 1985. Addis Ababa.

McDonald P, Edwards RA, Greenhalgh JFD, Morgan CA (1995). *Animal Nutrition* (5th edition) Longman Scientific and technical, John Wiley and Sons. Inc., New York.

McDowell LR (2003). *Minerals in animal and Human nutrition*, 2nd ed., (Elsevier, Amsterdam, the Netherlands).

Meissner HH, Koster HH, Nieuwoudt SH, Coetze RJ (1991). Effects of energy supplementation on intake and digestion of early and mid-season ryegrass and Panicum/Smuts.

Mugeriwa JS, Christianson JA, Ochetim S (1973). Grazing behavior of exotic dairy cattle in Uganda. *East Afr. Agric. Fores. J.* 19: 1-11.

Muriuki HG (2003). *A Review of the small-scale dairy sector - Kenya*. In: Milk and Dairy Products, Post-harvest Losses and Food Safety in Sub- Saharan Africa and the Near East. FAO. Rome.

Mustafa AF, McKinnon JJ, Christensen DA (2000). The nutritive value of thins tillage and wet distillers' grains for ruminants. *Asian-Aus. J. Anim. Sci.* 13: 1609-1618.

Norton BW (1982). *Differences between species in forage quality*. P. 89-110. In: J.B. (ed). Nutritional limits to animal production from pastures. Proceedings of an international symposium held at St. Luica Queensland, Australia, August 24-28, 1981. Common wealth agricultural bureaux. U.K.

Seyoum Bediye, Zinash Sileshi (1995). *Chemical composition, in vitro digestibility and energy value of Ethiopian feedstuffs*. In: Proceedings of the 3rd Annual Conference of the Ethiopian Society of Animal Production, 27 - 29 April 1995, Addis Ababa, Ethiopia, pp. 307 – 311.

Statistical Analysis System (SAS) (2002). *SAS/STAT guide for personal computers*, version 9.0 editions. SAS Institute Inc., Cary, NC, USA.

Tamene Temesgen (2008). *Genetic gain and morpho-agronomic basis of genetic improvement in grain yield potential achieved by faba bean breeding in Ethiopia. An M.Sc. thesis* presented to the school of graduate studies of Hawassa University.

Van Kempen L (2001). Infrared technology in animal production. *World's Poultry Science Journal,* 57: 29–48.

Van Soest PJ (1994). *Nutritional Ecology of the Ruminant*, 2nd ed., Cornell University, Ithaca, NY, pp. 476.

Yifru Teklu (1998). *Genetic gain in grain yield potential and associated agronomic trait of tef (Eragrosis tef (Zucc.). Trotter). An M.Sc. thesis* presented to the school of Graduate studies of Alemaya University.

Zinash Sileshi, Aschalew Tsegahun, Alemu Yami, Azage Tegenge (2001). *Status of livestock research and development in the highlands of Ethiopia*. In: P.C., Wall. (Ed), Chapter 1. Wheat and Weeds: Food and Feed. Proceeding of two stockholder workshops, 10-11 Oct. 2000. Mexico City, Mexico. pp 227-250.

Zinash Sileshi, Seyoum Bediye, Lulseged Gebrehiwot, Tadesse Tekletasdik (1995). *Effect of harvesting stage on yield and quality of natural pasture in the central high lands of Ethiopia*. In: Proceedings of 3rd national conference of the Ethiopian society of animal production. 27-29, April 1995, pp. 316-322. Addis Ababa, Ethiopia.